# Introduction

From the beginning of history, many people have wondered what everything that is observed in the world around us is made of. In the early days, the Greeks thought everything existed of only four elements: water, air, fire and earth. Throughout the centuries, the answer to the question changed in consequence of new discoveries and ideas in fields like chemistry and physics. Not only does the answer change through time, but it also depends on whom you are asking. Medical doctors like to believe it is all about strings of DNA and genes. For chemistry students it all boils down to atoms and electrons and nuclear physicists are only interested in protons and neutrons. And they all are right in their own way. Dissect DNA and genes and no life is possible; the atom (molecule) is the smallest piece of material that still carries the properties of that material and nuclear reactions take place by neutrons and protons. Who needs to know more? We (high energy physicists) do! We go to even smaller dimensions and believe everything is ultimately made of quarks, leptons and the forces acting between them.

As simple as this answer may seem, there is a lot more to particle physics. These elementary particles, as we call them, for instance, come in several flavours; 'up', 'down', 'charm', 'strange', 'top' and 'bottom' (or 'beauty') quarks, electrons, muons, taus and their neutrinos. All particles have anti-particles which are the same as the corresponding particles but have opposite charge (and other additive quantum numbers). There are four standard forces that act on these particles: the gravitational, strong, weak and electromagnetic forces. Interactions between particles take place through 'messengers': bosons. Each force is characterised by its own boson(s): the graviton, gluon, $W^{\pm}$ and $Z^0$, photon, respectively.

Quarks are confined and cannot be detected separately. They form hadrons, which can be classified as mesons and baryons (anti-baryons). Mesons are combinations of a quark and an anti-quark, baryons (anti-baryons) consist of three quarks (anti-quarks).

Quark and lepton physics is described in the so-called 'Standard' Model. However, there are quite a number of free parameters and gravitation is not included. Furthermore, although there is no need for any of the particles to have mass, we very well know from every-day experience that (most) particles are massive. There is a theory to overcome this problem. It is widely believed that the particle's interaction with the so-called Higgs field causes a particle to be massive. The Higgs particle corresponding to this field has not (yet) been discovered and its mass is one of the free parameters of the Standard Model.

High energy physicists 'have a dream' : All forces unite! Such a theory is called Grand Unification, describing the energy region where all forces act as one single force. The idea is that high-energy phenomena can be described in a simple way, but that symmetry breaking hides the simplicity of nature and makes it as complicated (and thus challenging) as it is now.

As difficult as some phenomena can get, they can sometimes be simplified by the use of (approximate) symmetries. One well-known symmetry is that of the u and d quarks (isospin symmetry), which arises since the mass difference is much smaller than the masses $m_{\mathrm{u}}$ and

$m_d$ associated with quark confinement, set by the QCD scale $\Lambda_{QCD}$. Predictions based on this symmetry can be made by applying a so-called effective theory where the mass difference is set to zero. Corrections then come from an expansion in the (small) parameter $(m_u - m_d)/\Lambda_{QCD}$.

Another symmetry is that of the heavy quarks. This arises because the mass of a heavy quark Q is much larger than $\Lambda_{QCD}$. Predictions come from a heavy-quark effective theory where the mass of the heavy quark is set to infinity. Corrections are obtained from an expansion in terms of $\Lambda_{QCD}/m_Q$. Light quarks interacting with such a heavy quark are blind to the heavy-quark flavour/mass and spin. Therefore, the excitation spectrum for any system containing a heavy quark and light quarks will be the same. This fact can be used to derive predictions for a heavy-quark system by extrapolating results obtained for another heavy-quark system. Each spectral level can be characterised by the light-quark quantum numbers: $\vec{j}_q = \vec{s}_q + \vec{L}$, were $\vec{s}_q$ is the spin of the light quark, $\vec{L}$ is the orbital momentum of the system and $\vec{j}_q$ is the total angular momentum of the light quark. Each level is a degenerate doublet in total angular momentum: $J_\pm = j_q \pm s_Q$, where $J_\pm$ is the total spin of the system and $s_Q$ is the spin of the heavy quark. The orbitally excited ($L$=1) beauty mesons ($B^{**}_{u,d}$ ), the main subject of this thesis, can thus be indicated by $j_q = 1/2$ ($J_+$ = 1 and $J_-$ = 0) and $j_q = 3/2$ ($J_+$ = 2 and $J_-$ = 1). They decay strongly into a $B_{u,d}$ or $B^*$ meson and a pion. The pion can be either charged or neutral. Since both channels are measured in this analysis, the isospin symmetry can be checked.

First, the heavy-quark symmetry and effective theory will be discussed in chapter 1. This will be followed by a description of the theoretical predictions and existing experimental results on excited B mesons. In chapter 2, the experimental setup is described. Special attention is paid to the Silicon Microvertex Detector, which is of great importance for the analysis described in this thesis. In the third chapter, the tools for obtaining the direction and the energy of the B meson and the criteria for the selection of charged and neutral pions are described. In the fourth chapter, the $B\pi^\pm$ and $B\pi^0$ mass distributions are obtained and fitted, and the relative production rates are compared. As a completion of the excited beauty states, the analysis is repeated for $B^*$ decays to $B\gamma$ at the end of the chapter. The systematic errors are described in chapter 5. Chapter 6 follows with the conclusions and a comparison to the results of other experiments.